

METHOD FOR IMPROVING ASH RATE UNIFORMITY IN
PHOTORESIST ASHING PROCESS EQUIPMENT

5 BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to semiconductor processing
10 equipment and more particularly to plasma ashing
equipment.

2. DESCRIPTION OF THE RELATED ART

15 Certain types of equipment used in the ashing
process for the removal of photoresist during the
processing of integrated circuits and/or micro-
electromechanical-mechanical (MEMS) devices, exhibit an
ash rate non-uniformity from the edge-to-center of the
20 wafer. This effect, caused by a semi-stagnation of the
plasma gas flow at the center of the wafer as compared to
the outer edge of the wafer, results in a decrease in the
rate of photoresist removal from the edge to center of
the wafer. In the past, this edge-to-center ash rate
25 variation has been minimized by manipulation of several
different processing parameters, including pressure,
temperature, power, bias direction, and gas
concentrations. Typically, these parameters are

optimized for a particular process and saved as the process recipe.

Down-streaming plasma reactors often employ grid
5 plates between the plasma generation region and the target wafer. These grid plates are used to ensure that only neutral reactive specie, for example, oxygen and fluorine atoms, make their way to the work piece (target wafer) to ash away the photoresist. Neutral reactive
10 specie minimizes the unwanted side effects; i.e., ion bombardment on CMOS transistors and other component structures. Grid plates are made of metal (example aluminum) with drilled holes to allow the excited gas or plasma to pass through to the target wafer. These plates
15 are positioned such that non direct line-of-sight exist for the gas or plasma to reach the wafer.

A diagram for a down-streaming plasma reactor is shown in Figure 1a. This type asher employs grid plates
20 2 and 3, with a separation gap 5, between the plasma generation region and the work piece (wafer). The grid plates consist of metal plates with equal sized holes 6, as shown in Figure 1b. The upper grid plate 2 and lower grid plate 3 are aligned so there is no direct path for
25 the gases to pass through to the wafer. The plasma gases 1 are applied to the upper grid plate 2 and exit through

the holes in the lower grid plate 3. The purpose of the grip plates is to ensure that only neutral reactive specie, such as oxygen and fluorine atoms, make their way to the wafer where the photoresist is to be ashed away.

- 5 These neutral reactive specie minimize unwanted side effects; i.e., ion bombardment which is destructive to the CMOS transistors and other structures on the wafer. However, as mentioned above, the grid approach can cause stagnation of gases towards the center of the wafer,
- 10 which cause a faster rate of photoresist removal near the edges of the wafer. This in turn can be destructive to the product being processed.

- There is a need to improve the plasma ashing process
- 15 to better compensate for this non-uniformity in the photoresist removal rate. This variation in ash rate across the wafer is further compounded as wafer size is increased. With 300mm diameter wafers expected to become the norm in the not too distant future, ash rate
- 20 uniformity will become even more critical. The invention disclosed herein addresses this need.

- U. S. Patent 5,948,283 is an example to one approach to addressing this problem by providing supplemental heat
- 25 to the wafer in treatment.

SUMMARY OF THE INVENTION

Edge-to-center photoresist ash rate uniformity in
5 the processing of wafers for integrated circuit
fabrication and/or micro-electro-mechanical (MEMS)
devices can be improved significantly by properly
controlling the gap distance or hole size of the grid
plates used in plasma ashing process equipment.
10 Specifically, down-streaming plasma ashers that employ
grid plates are sensitive to the grid plate separation
(gap distance) between grid plates, especially when
employed in lower temperature ($<100^{\circ}\text{C}$ chuck temperature)
ashing operations. By providing a continuously variable
15 or stepwise variable gap separation between the grid
plates, the ash rate uniformity across the wafer can be
improved. Alternatively, variable hole sizes in equal
spaced grid plates can be used to accomplish the same
results.

20 This improvement increases the ash (photoresist
removal) rate at the center of the target wafer to a
point where it is in close proximity to the ash rate near
the edges of the wafer. Overall, the improvement of this
25 invention reduces both the process time and the amount of
undesirable particle generation, which can damage the
product being fabricated.

DESCRIPTION OF THE VIEWS OF THE DRAWINGS

The included drawings are as follows:

5 Figures 1a and 1b are a schematic and hole pattern layout, respectively, for the grid plates in a typical plasma asher. (prior art)

Figures 2a and 2b are a schematic and hole pattern layout, respectively, for the stepwise variable gap
10 grid plate separation improvement method of this invention.

Figures 3a and 3b are a schematic and hole pattern layout, respectively, for the continuous variable gap grid plate separation improvement method of this
15 invention.

Figures 4a and 4b are a schematic and hole pattern layout, respectively, for the variable hole size, equal gap grid plate separation improvement method of this invention.

20 Figure 5 is a block diagram for a plasma ashing machine, which uses the grid plate assembly of this invention to control ash rate uniformity.

DETAILED DESCRIPTION

By reducing the variability of the ash rate across the target wafer, shorter process times can be employed, thereby reducing the amount of over-ashing required to compensate for edge-to-center ash rate differences.

Lower temperature ($<100^{\circ}\text{C}$) processing is particularly sensitive to manufacturing variations in grid fabrication. As little as 10-15% grid gap distance can swing ash rates as much as 50%. This characteristic allows for the ash rate uniformity to be controlled by variable grid plate separation. The grid plate separation needs to be greater at the center of the wafer in order to compensate for the plasma gas flow differences between the edge-to-center of the wafer. This invention improves the ash rate uniformity by accurately varying the gap spacing between the grid plates. This approach allows for more uniform plasma gas flow and therefore more uniform photoresist removal across the device.

Figure 2a shows a first embodiment of the invention where the grid plate separation gap is made larger in a stepwise manner over the center region of the target wafer. The grid plates are comprised of an upper plate

20 and a lower plate 21 and are separated by a gap 23.

In this case, a stepwise impression 22 is made in the center portion of the upper grid plate 20. This in turn, provides larger gap spacing 23 to be employed over the

5 center of the target wafer. Figure 2b shows the hole pattern 24, which maintains equal sized holes in the upper and lower grid plates 20 and 21, respectively. Gap spacing typically varies in the neighborhood of 0.035 to 0.050 inches. The wider gap near the center of the grid
10 plates allows greater amounts of plasma gases to flow in this normally semi-stagnated area located around the center of the target wafer.

More accurate control of the ash rate uniformity is
15 realized in the second embodiment of this invention, as shown in Figures 3a and 3b. Here the gap 32 between upper grid plate 30 and lower grid plate 31 varies continuously from edge-to-center of the grid plate assembly. This eliminates the step function of
20 embodiment one and provides more uniform plasma gas flow over the entire target wafer. As illustrated in Figure 3b, the grid plate holes 33 are all of equal size. As before, the grid plate gap spacing varies in the range of 0.035 to 0.050 inches.

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A third embodiment of the invention is depicted in Figures 4a and 4b. In this case the grid plates 40 and 41 maintain a constant gap spacing 42, but the hole diameters 43 vary across the plates from edge-to-center, with the larger holes located near the center. The overall effect of this approach is the same as the earlier embodiments in that the plasma gas flow rate is increased in the semi-stagnation area near the center of the target wafer.

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Figure 5 is a block diagram for a plasma ashing machine 50, which uses the grid plate assembly 512 of this invention. This machine is comprised of a plasma chamber 51 with other necessary sources connected to the chamber, including a RF power supply 52, a gas distribution system 53, a vacuum system 54, and a heater and temperature controller 55. These sources are combined to control the environment inside the plasma chamber 51. The wafer 514 to be processed (work piece) is placed in the plasma chamber 51. Plasma gases 511 from the plasma source 510 are applied to the upper grid plate of the grid plate assembly 512. These gases are neutralized (de-ionized) going through the metal grid plates so that neutral reactive particles 513 exit the lower plate of the grid plate assembly 512. The variable gap 515 between the upper and lower grid plates is made

greater from the edge-to-center of the grid plate assembly 512. This variable grid plate gap allows for more of the gases to flow in the center portion of the work piece, overcoming the semi-stagnation which normally occurs in this area and as a result providing faster photoresist removal on the work piece. By controlling this variable gap 515, the ash rate uniformity is controlled, allowing for shorter processing times and higher performing parts since the amount of over etching is considerably reduced.

While this invention has been described in the context of three embodiments, it will be apparent to those skilled in the art that the present invention may be modified in numerous ways and may assume embodiments other than that specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention.

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